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MUON ELECTRON SCATTERING AT NAL

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It will be the purpose of this note to point out some of the interesting electrodynamic problems which can be investigated with positive and negative muons of high energy scattered from electrons. The discussion of muons as a nuclear probe will no doubt be covered by others. The desire for very high energy muons is motivated by the kinematic situation encountered when the target particle in a scattering situation is very light. The invariant four-momentum transfer in a μ-e scatter is given by:

$$t \equiv (P_{ef} - P_{ei})^2 = 2m_e T_e$$

A 100 GeV/c muon is capable of causing t to assume values up to 0.09 GeV^2. Four-momentum transfers of this magnitude are adequate for the experiments described below.

A-Two Photon Exchange Effects: Nikishov[1] has calculated the scattering of two unlike spin 1/2 fermions to order α^3 (including the radiative corrections to the lowest order Feynman diagram and the two photon exchange diagrams). The results predict a rather large asymmetry in the scattering of positive and negative muons from electrons. With muons of 100 GeV/c, the cross section for the negative muon is larger than that fot the positive muon by as much as 10%. Such an asymmetry should be easily measureable. (It is interesting to note the effect is still 3% with 20 GeV/c muons). Only one experiment[2] has been done to date to test for a possible asymmetry, but this experiment lacked sufficient sensitivity to reveal the two photon contribution. The μ-e experiment requires a muon beam which can select either sign of muon, and would benefit from a fairly narrow beam momentum spread. Moderate beam intensities would be required (perhaps 10^4 - 10^5 per sec).

B-Radiative Corrections: The radiative corrections to the μ-e scattering have been calculated by Gorge et. al.[3] and applied to the results of a μ-e scattering experiment by Backenstoss et. al.[4] The corrections reached as high as 30% although the muon beam momentum was centered at only 8 GeV/c. It would be interesting to verify these calculations at the corresponding points for the considerably higher energies available at NAL. This experiment involves a measurement of the absolute cross section to an accuracy of about 1%. This is harder than the asymmetry experiment, but should be readily possible. The experiment requires good beam momentum resolution and moderate intensities as in A.

C-Polarization Effects: By passing high energy muons through magnetized iron, the dependence of the μ-e cross section on electron helicity amplitudes can be studied. This effect was measured in the Backenstoss experiment (Ref. 4), which found agreement with the theory. This result could be improved in statistical precision by a carefully designed experiment. The very high energies available at NAL would permit an absorption type experiment with fewer of the well-known multiple scattering and nuclear collision loss problems. The main improvement would probably be statistical, and high intensity would be essential (10^6 per sec).

D Esoterica: After the obvious experiments have been considered, there always lurk in the minds of men the sort of questions which not only cannot be answered until the relevant experiment is completed, but perhaps not even properly asked. In such cases, the best procedure seems to be to calculate the kinematics, and if these look favorable, to do the experiment with an open mind and careful attention to detail. In this category belong such speculations as the nature of the μ-e difference and the role of muon number; the possibility of structure in the μ-e elastic scattering (form factors); or the existence of a new process(es) for leptons (such as charge exchange scattering).

In these speculative areas, the relevant kinematics argues fairly strongly against an attempt to measure form factors from μ-e scattering. This is especially disappointing in view of the recent work done in μ-p elastic scattering[5], in which, together with the large amounts of elastic e-p scattering data, it seems possible to verify the existence or nonexistence of a lepton form factor. It would be nice to close the triangle by scattering muons and electrons and show the absence of structure. The very small t attainable even at NAL energies makes this program unattractive.

The μ-e charge exchange scattering ($\mu^+ + e^- \rightarrow \mu^- + e^+$) would involve a change in muon number and is probably forbidden. Nevertheless, it might be of interest to search for this process if a sufficiently discriminating trigger can be developed. Here the availability of very high energy muons with high intensities could make such a search attractive. An unambiguous identification of μ^- seems to be essential.

Just how one might further investigate the nature of the μ-e difference through μ-e scattering is not the least bit clear. One is limited in speculation primarily by ones imagination and the conservation of energy. Muon beams at NAL energies extend the region of interest. Some new ideas may develop here as some of the other experiments mentioned above proceed.

In conclusion, I suggest that the categories A-D list some interesting directions in which to proceed if a high energy muon beam is developed at NAL. The experiments above are more or less listed in the order of increasing difficulty if not necessarily in order of interest.

REFERENCES

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